

BIOLOGICAL BULLETIN

MODIFICATION OF RESPONSE IN AMÆBA.

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Gibbs and Dellinger ('08) and Schaeffer ('17) maintain that *Amœba* has the power of selecting food. The former hold that the kind of food preferred changes under various conditions, and they suggest that changes in the kind of food selected is the result of a process of learning based upon the method of "trial and error." One of us (Mast '10) in preceding observations found that when the tip of a pseudopod of an amœba comes in contact with a highly illuminated region in the field it stops; then others are sent out in succession in the same general direction, each one stopping when it comes in contact with the light, until suddenly one is sent out in a markedly different direction, avoiding the illuminated region altogether. It is maintained that this abrupt change in the direction of the formation of the pseudopods, constituting a profound modification in the response to a given stimulus, is dependent upon the preceding experience of the individual, *i.e.* repeated contact with the strong light.

The specimens used in the following experiments were obtained from the cultures in the laboratory, most of which had been stocked with material from a stream near the campus. They were of the proteus type. Each amœba was isolated on a glass slide in a drop of its culture-fluid under a cover-glass, the edges of which were sealed with vaseline. Each amœba was adapted to darkness before using.

The observations were made in the dark room. An area of intense light was obtained by focusing on the slide under the microscope, by means of the reflector and an Abbe condenser, an image of a portion of the luminous filament of an incandescent Mazda lamp placed in a light-tight box. The rays of the filament passed through a very narrow slit in the box. The image had

clearly defined edges and furnished a band of intense light across the field. The slide was adjusted so that the amœba was within a distance equal to approximately half its length from the light with the pseudopod or pseudopods progressing towards it. If the pseudopod did not stop when it came in contact with the light the amœba was discarded. If it stopped the behavior of the amœba was observed until it definitely moved away from the light, and the number of pseudopods which made contact with it was recorded. After this the light was shut off, and the amœba was left in darkness until the next trial was made. In this way each individual was given twenty-seven trials.

The interval between trials was approximately three minutes except in the following as recorded in Table I: individual *B*, trials 16-17 and 23-24, 24 hours; individual *D*, trials 15-16, 22 hours; individual *E*, trials 8-9 18 hours, 16-17, 48 hours, and 21-22, 24 hours; individual *F*, trials 8-9, 50 hours, and 20-21, 20 hours; individual *G*, trials 16-17, 16 hours, and 24-25, 3 hours. During these intervals the amœbæ were kept on their slides in darkness undisturbed.

The behavior of a typical individual is illustrated in Fig. 1 by sketches representing all of the trials in the series. By referring to this figure it will be seen that while during the first part of the series there was something of a persistence on the part of the amœba to attempt to proceed in its original direction—notably 7 attempts in trial 4—there was but little in the latter part of the series—a total of only 5 attempts during the last 14 trials.

The results obtained in all of the tests are presented in Table I. This table shows that the number of pseudopods which came in contact with the light before the direction was changed decreased in general as the number of trials increased in each series, that there was a similar decrease in the total contacts of all amœbæ for corresponding trials, and also in the totals of consecutive groups of three trials. Amœba *B* made 10 contacts with the light in the first three trials; with trial 4 a general decrease begins. A total of 20 pseudopods made contact in the first 14 trials of the series, and a total of 9 in the last 13. In the series of amœba *D* there were 5 contacts in the first 6 trials but none at all in the remaining 21 trials. Amœba *E* made 21 contacts in the first 14 trials—11 of these were in the first 4—and 5 in the last 13

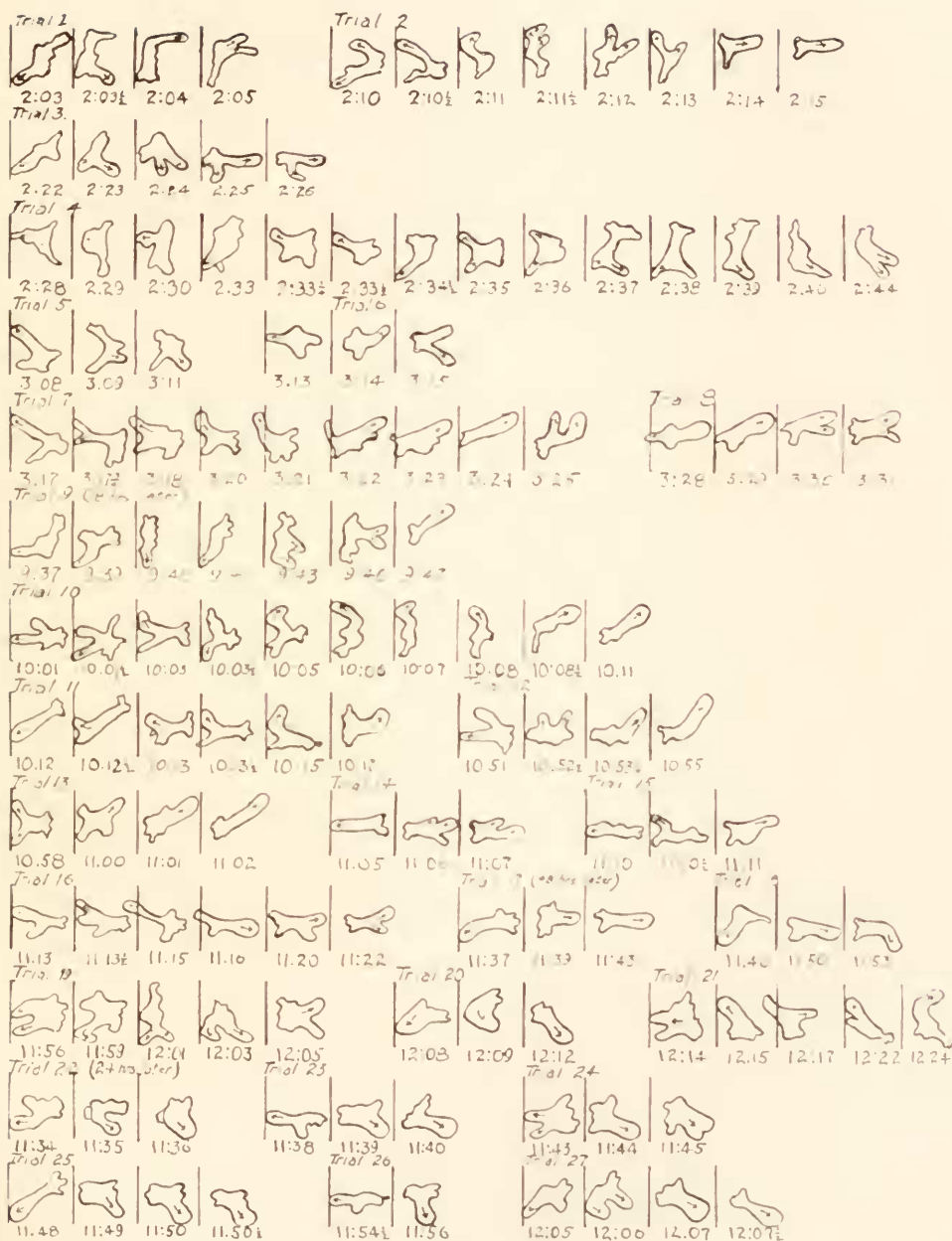


FIG. 1. A series of diagrammatic sketches illustrating the behavior of *Amoeba E* for twenty-seven trials. The straight lines of equal length represent a band of light. The outlines of the amoeba describe its position in relation to the light at the time given below in each individual sketch. The arrows show the direction of protoplasmic streaming.

trials. *Amoeba F* made no contacts until trial 8; between trials 8 and 15 there were 8 contacts, while in the remaining 12 trials there was but one contact. There was one contact in the first trial of *Amoeba G*, then none until the 7th, when a reversal began and persisted very generally through the 17th, by which time 23 contacts had been made; in the remaining ten trials there were 8 contacts.

TABLE I.

RESPONSE OF AMOEBA TO CONTACT WITH A HIGHLY ILLUMINATED REGION IN THE FIELD.

Designation of Trials.	Number of Pseudopoda that Came in Contact with Light in Each Trial.					Total Contacts for All Individuals in Each Trial.	Total Contacts for All Individuals in Groups of Three Consecutive Trials.
	B.	D.	E.	F.	G.		
1	4	0	0	0	1	5	18
2	3	0	3	0	0	6	
3	3	3	1	0	0	7	
4	0	0	7	0	0	7	
5	3	1	0	0	0	4	
6	0	1	0	0	0	1	13
7	1	0	2	0	1	4	
8	2	0	0	2	4	8	17
9	0	0	2	1	2	5	
10	0	0	4	0	1	5	
11	3	0	2	2	2	9	14
12	0	0	0	0	0	0	
13	0	0	0	1	2	3	
14	1	0	0	0	4	5	12
15	0	0	1	2	1	4	
16	1	0	1	0	1	3	
17	0	0	0	0	5	5	8
18	0	0	0	0	0	0	
19	0	0	1	0	0	1	
20	0	0	0	0	1	1	6
21	2	0	2	0	0	4	
22	0	0	0	1	0	1	
23	1	0	0	0	3	4	8
24	0	0	0	0	3	3	
25	4	0	0	0	1	5	
26	1	0	0	0	0	1	6
27	0	0	0	0	0	0	

The totals by groups of three consecutive trials fluctuate between 18 for the first group, 12 for the middle and 6 for the last. In other words there is a modification of response in the sense that the number of attempts to continue in the original direction after meeting the light decreases in general as the number of trials of the series increases.

It will be remembered that each series was interrupted irregularly by longer intervals of time, usually about a day or longer. Despite this there is a general constancy of the tendency throughout each series. This seems to indicate ability to retain for some time the modification of response.

These experiments were repeated 18 months after the preceding portion of the paper was completed. Two individuals were used and a series of 18 readings approximately 3 minutes apart were obtained with each. The total number of contacts made by these two individuals in groups of three consecutive trials beginning with the first follows: 20, 9, 10, 6, 7, 4. The results obtained in these observations are consequently in harmony with those obtained in the preceding observations.

SUMMARY.

When *Amœba* repeatedly comes in contact with a band of intense light the number of attempts to continue in the original direction decreases as the number of trials increases.

This indicates that there is some change in *Amœba* that is analogous to what is called "learning" in the higher animals.

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